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ASSESSMENT OF SAFETY AGAINST FLOODING IN THE NETHERLANDS

Discussion paper transmitted by the Government of the Netherlands */

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1. INTRODUCTION

With the Flood Protection Act of 1996 (FPA) a new era in water defence management in the Netherlands has started. The purpose of this Act is to provide and to maintain long-term safety. Within a few years (2001) the program on extensive reinforcement of the sea- and river defence system will be completed, nearly half a century after the beginning of the works which were initiated by the 1953 flood. The central government wants to consolidate the safety level as achieved at the time of completion. The management of the flood defences is crucial for the long term maintenance of the safety achieved. For this reason managers are obliged (by FPA) to check the technical state of their flood defences every five years against the current safety specifications. This concept of how to *maintain* the achieved safety level of the water retaining structures is new in the Netherlands. To facilitate the safety assessment a technical guideline was introduced. The main topic of this paper is the safety assessment in relation to the technical guideline and the impact on management and maintanance.

2. THE FLOOD PROTECTION ACT

The low-lying regions of the Netherlands are divided into 53 so-called "dike ring area's". Figure 1 gives a (fictive) example of a dike ring area, which consists of various types of water defence structures: dikes, sluices, locks, dunes, etc. The circle of linked water defences forms the protection of the dike ring area against flooding. Each dike ring area has an acceptable level of risk (safety standard). These safety levels are laid down in the FPA and have to be maintained by the managing local administrations. The day-to-day management of flood defences is not primarily the responsibility of the central government, but of the 41 district water boards (local administrations). The Provinces perform a supervisory function, with the central government acting as chief supervisor.

The FPA gives rules for:

- the supervision of the local administration by the regional authority (Province),
- the supervision of Provinces by the National Authority (Ministry of Transport, Public Works and Water Management),
- the provision of (technical) guidelines for assessment, design and management,
- the contents of data-bank registers, to be set up by the local administration,
- the hydraulic boundary conditions to be used for safety assessment and design,
- the procedure to be followed by the local administration and by the Province for the justification reports,

- the reponsibilities regarding maintaining of the coastline,
- the training of personnel, volunteers ("dike army") and material for operation under extreme near-failure conditions,
- the grants for management and maintenance, and for new defence works,
- the installation of regional boards of flood control.

3. MANAGEMENT AND MAINTENANCE

The management of a water defence can be characterized by the total of the activities, required to guararantee that the functions of the water defence are up to predefined standards. The standard for the safety function is that the manager is responsible for a long lasting maitenance of the safety level as has been laid down in the FPA. By means of an adequate maintenance and control system of the water defence structures the manager aims to secure that the actual quality of the relevant condition parameters does not decrease to a level lower than the acceptable failure limit. For this purpose the so-called preventive condition-based maintenance strategy has been adopted. This strategy distinguishes three limits of quality levels of the condition parameters (see Figure 2). These limits are:

- warning limit: quality level at which a more intensive control of the condition parameters is needed (higher inspection frequency),
- action limit: quality level at which repair measures should be prepared and carried out before the failure limit has been reached,
- failure limit: quality level that is just acceptable from the safety requirement. If the condition decreases below this level the water defence system will not provide sufficient safety.

The margin between the action limit and the failure limit will depend on the inspection frequency and the mobilization time for the construction of repair measures. An optimum maintenance and control strategy will be obtained by considering the minimum cost of repair and inspection, on the condition that the probability of exceeding the failure limit is sufficiently low.

Although most of the before mentioned aspects are familiar in structural engineering (steel and concrete structures) the applications of a systematic condition-based maintenance approach for hydraulic and geotechnical engineering are very limited. This may be caused particularly by the considerable length of the dike sections, the heterogeneous composition of the dike elements including the variability of the failure mechanisms and associated damage patterns.

One of the managers' obligations of the FPA is to make a data base register of the water defences. In this the actual state as well as the as-built state has to be described. This database facilitates not only the five year safety check but also the day-to-day management. The database register contains all physical qualities of the administered objects and related aspects inside the influence zone:

- the boundaries of the influence zone; this zone includes those areas of adjoining sea bed and land where processes are linked in some way to the behaviour of the defence works,

- a description of the as-built situation and the actual situation, including longitudinal and cross-sections, geotechnical profiles etc.,
- a list of issued licenses,
- an ownership and farming-out register,
- a map with all cables and pipes owned by public utilities, oil companies etc.,
- a damage record,
- a record of executed maintenance,
- boundary conditions (hydraulic, geotechnical, traffic, etc.).

4. BASICS OF THE SAFETY ASSESSMENT

4.1 Introduction

The above mentioned failure limit of a water defence structure is a measure for the actual safety and depends on three elements:

a) the safety standard, as accepted by society,
b) the way of modelling the (hydraulic) boundary conditions (loads) and
c) the way of modelling of the strength of the structure.

These three elements followed, and still follow, a development process. This means that safety assessment is not a static event, but a continuing process.

4.2 The safety standard

The safety standard at this moment varies from 1/1,250 to 1/10,000 per year, being the probability of occurence of the design flood. The water defences must be able to withstand the load related to this *design flood*.

By defining the safety in terms of hydraulic loads, the actual probability of *flooding* of an area surrounded by a dike is not taken into account. Neither are the consequences of flooding taken into account directly. In order to come to a flooding related safety standard the Dutch Technical Advisory Committee on Water Retaining Structures (TAW) has started a resarch programme. The research focuses on six areas, in order to achieve an accurate safety philosophy based on the risk of flooding:

1. boundary conditions and loads,
2. strength of flood defences and failure mechanisms,
3. breach growth ans risk of flooding,
4. damage and casualties,
5. case studies,
6. considerations for setting standards.

In the coming years, the TAW will develop the research programme step by step. The results of the first case studies are expected in the autumn of 1998.

4.3 The hydraulic boundary conditions.

The hydraulic boundary conditions (water level, waves, wind) are directly related to the safety standard (design flood). The loads are also influenced by the following aspects:

- recession of the coastline and/or lowering of the foreshore,
- sea-level rise,
- local land subsidence due to lowering of polder water levels and mining of oil, gas and salt,
- more advanced calculation methods.

In order to avoid confusion and different local interpretations, the Minister of Transport, Public Works and Water Management has translated the safety standard into hydraulic boundary conditions in 1996 for all the water defence sections of a dike ring area. This report will be updated every five years.

4.4 The strength of the structure; the technical guideline

The stability of the dike and therefore the water retaining function can be endangered in many ways. The most important failure mechanisms are overflowing, wave-overtopping, sliding of the inner slope, erosion of the outer slope, sliding of the outer slope, sliding of the foreshore, liquefaction of the foreshore and piping. These mechanisms have been modelled in calculation methods and have been laid down in guidelines for design, produced by the TAW. The technical methods for calculating structural safety in these guidelines are existing, proven methods.

On the foundation of this knowledge and these methods the TAW also has developed the appropriate tool to enable the manager to carry out the safety assessment in the context of the Flood Protection Act. This concerns a method for the assessment of the safety of water defences, laid down in a technical guideline, to be updated every five years. The technical guideline shows resemblence with the UK guideline on "floods and reservoir safety".

The guideline works with four functional quality scores: 'good', 'sufficient', 'doubtful' and 'insufficient'. The score 'good' means that the structure has the strength to withstand the design load. But even below design quality often the strength is sufficient to guarantee a condition that can be labelled as 'not unsafe' (see figure 3). These situations have been carefully investigated. The criterion 'start of failure' marks the situation of an unacceptable risk for the structure. Below this a functional quality improvement or renewal of the structure is necessary. If it is impossible to determine the quality with the available information, the preliminary score is 'doubtful'; in that case the manager has to make investigations into the condition of the structure.

5. THE SAFETY ASSESSMENT

5.1 Introduction

Every five years a manager has to report on the technical state and the safety level of his water defences. He must report to the Province. The Province examines these reports and sends an overall status-report for each dike ring area to the Ministry of Transport, Public Works and Water Management. The report of the manager to the Province must contain the following elements:

- a map of the present situation, together with additional information to form an idea of the characteristics of the water defences,
- a technical safety assessment of the water defences,

- a justification of the present management scheme in order to maintain the required safety level.
- a list of measures, nescessary to restore the water defences to the required safety level.
- Only the first two points are explained here.

5.2 Map and characteristics

In order to get an overall view of the types of water defences in his district, a manager must make a map (scale 1:10,000). On this map the various water retaining structures (dikes, dunes, sluices, locks, storm surge barriers) are, if possible, subdivided into characteristic sections. Per section a database with technical information has to be made. This information concerns aspects as:

- profile data: height, inner and outer slope, level and width of a berm, etc.,
- geotechnical data: D50 (dunes), core material characteristics (dikes), characteristics of the foundation layer, etc.,
- revetments: material classification and characteristics, thickness, location in the profile, etc.,
- hydraulic loads: waterlevel, wave height, wave period.

5.3 Technical safety assessment

The technical safety assessment can be carried out per section with the use of the database and the technical guideline. It has to be performed for the set of water defence structures that surround a dike ring area (as has been described in the above-mentioned map). The test scheme is shown in figure 4. Four independent assessment tracks have been established in the guideline: height (HT), stability (ST), gates (GT) for sluices and storm surge barriers, and the critical profile (CP) for dunes.

In figure 4 there are two structure types that need further explanation. Firstly the type "pipes/cables, houses, trees". Dikes often have objects in or on top of them, which have no water retaining function. Examples are pipes and cables, houses, pumping stations and trees. Even though these objects have no water retaining function in themselves, they can affect the main function of the dike, so their influence has to be taken into account. Secondly the type "junctions". The connection between two types of water defences needs special attention. The score of the two individual water defences can be 'good', but if the connecting structure between them is 'insufficient', the score for the whole dike ring is 'insufficient'.

To complete the technical safety assessment of a dike ring, an assessment form has to be filled out. An example of such a form is shown in figure 5. Each section of the dike ring area shows two scores per assessment track: one score based on the experience and expectations of the manager (B), and one score that follows from the assessment calculations (M). In most cases both scores will be the same. However, it may happen that the dike manager has the feeling that for a particular dike section an assessment formula is not applicable. In those circumstances he has the right to fill up a deviating score. This will be the signal for further research in that section and/or adaption of the assessment formula. By filling out the assessment form from figure 5 a survey of the condition of the whole dike-ring is achieved.

In order to save time the assessment calculations have three levels of complexity (see figure 6):

- general: use of the preliminary simple assessment method from the guidelines,

- detailed: use of the secondary assessment method from the guidelines,
- advanced: use of numerical models with the help of specialists.

General assessment is always used first because it is the easiest to apply and requires the least information about the structure. Detailed assessment is only used if no preconceived opinions can be expressed about the structure. The "grey" zone is smaller than that for general checking, as shown schematically in Figure 7 for the stability check of the top layer of a pitched slope protection.

6. EXAMPLES

In figure 1 the (fictive) dike ring area B is shown. In order to assess for example section d, a shipping lock, the main assessment tracks are:

- height (HT): is there sufficient height in order to keep the overtopping water within acceptable limits?
- stability (ST): deformation or movement of the construction; resistance against piping?
- gates (GT): strong enough and reliable closing procedure?

The assessment tracks have been laid down in flow diagrams. These have to be followed in order to come to a score. In this way all the assessment tracks have to be followed, leading to a final score for the section, in this case the lock.

As an example, the assessment track 'height' (HT) of a river dike (figure 1, section j) has been worked out. Figure 8 shows the flow diagram. From a simple check whether or not there is enough freeboard, the track leads in case of a positive answer towards the following question: 'is the crestheight up to standard according to the design guidelines?'. When the answer is 'yes', the score on HT is 'good'. Following the other routes of the flow diagram, only the scores 'sufficient' an 'insufficient' can be realized.

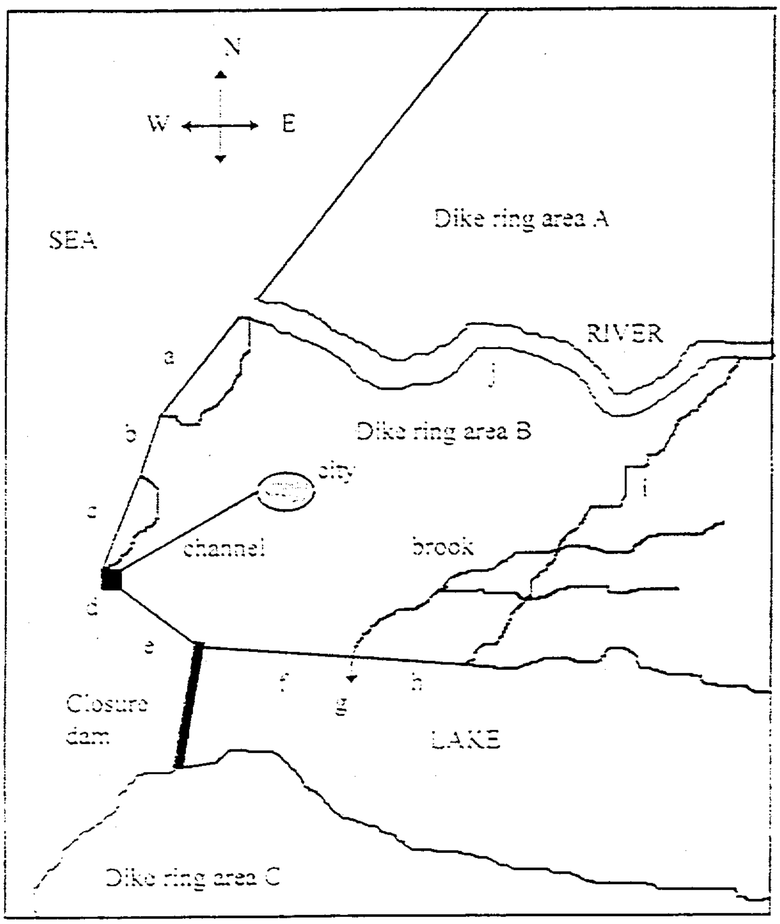
7. IMPLEMENTATION OF THE ASSESSMENT

The first round of safety assessment has to be completed in January 2001, five years after the Flood Protection Act has come into force. In the ideal situation this means that the water defence manager will fill his data base register and will make the assessment, using the technical guideline. In practice however, most managers cannot realise a full assessment before 2001 due to, for instance the following circumstances:

- the finishing of the initial reinforcement program is very time consuming and takes all the managers' attention,
- the filling of the data base register cannot be completed due to a limited number of geotechnical surveyors.

Therefore, the first check will be an extensive one. The assessment will be carried out with the data avaliable at that time. Meanwhile the technical guideline will prove it's applicability. At this moment the assessment is in it's early stages but nevertheless a number of suggestions for improvement of the guideline have reached the guidline's helpdesk. This will result in a new

version of the guideline by 2001. This improved guideline and a adequately filled data base register will be the foundation of a second round of the safety assessment, to be completed in 2006.



The dike ring area B has three potential threats from which flooding can occur:

1. the sea on the west side,
2. the lake on the south side and
3. the river on the north side.

The dike ring area is protected against flooding by a dike ring consisting of various water defences:
a. dune area
b. sea dike
c. dune area
d. lock
e. sea dike
f. lake dike
g. sluice
h. lake dike
i. high grounds (above storm surge level)
j. river dike

Figure 1 Example of a (fictive) dike ring area

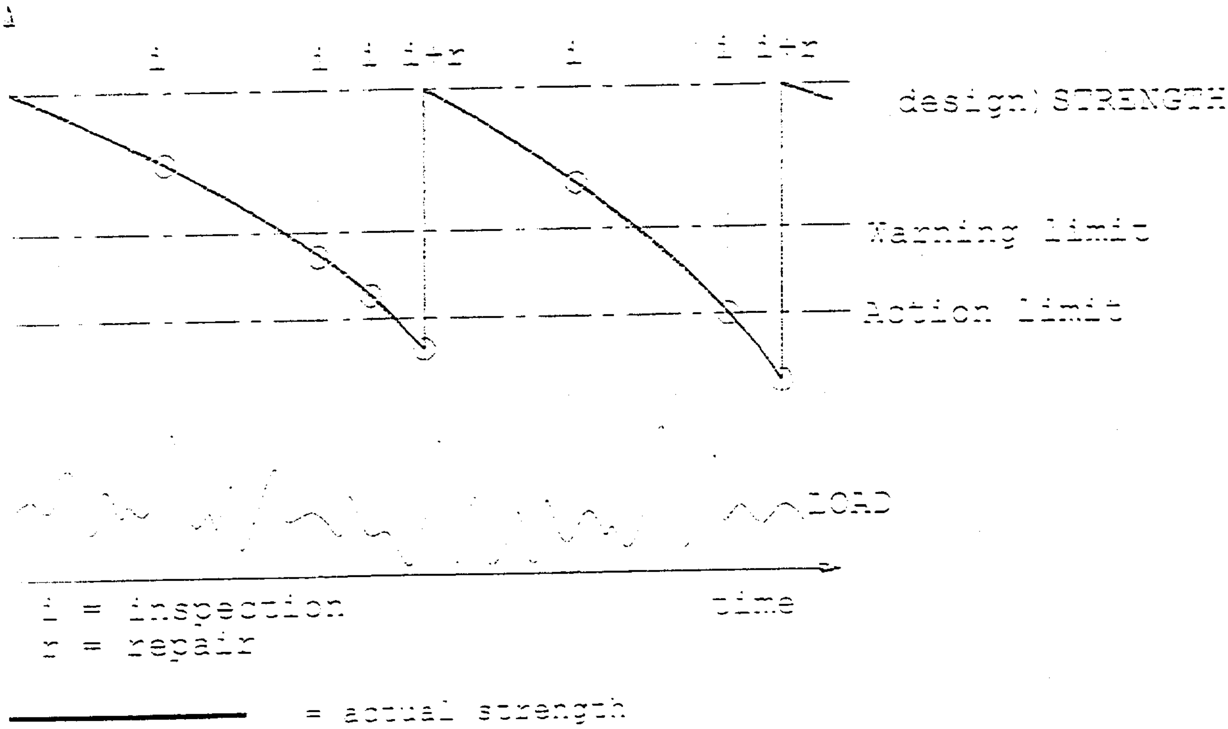


Figure 2 Three limits of quality level related to the strength of a water defence

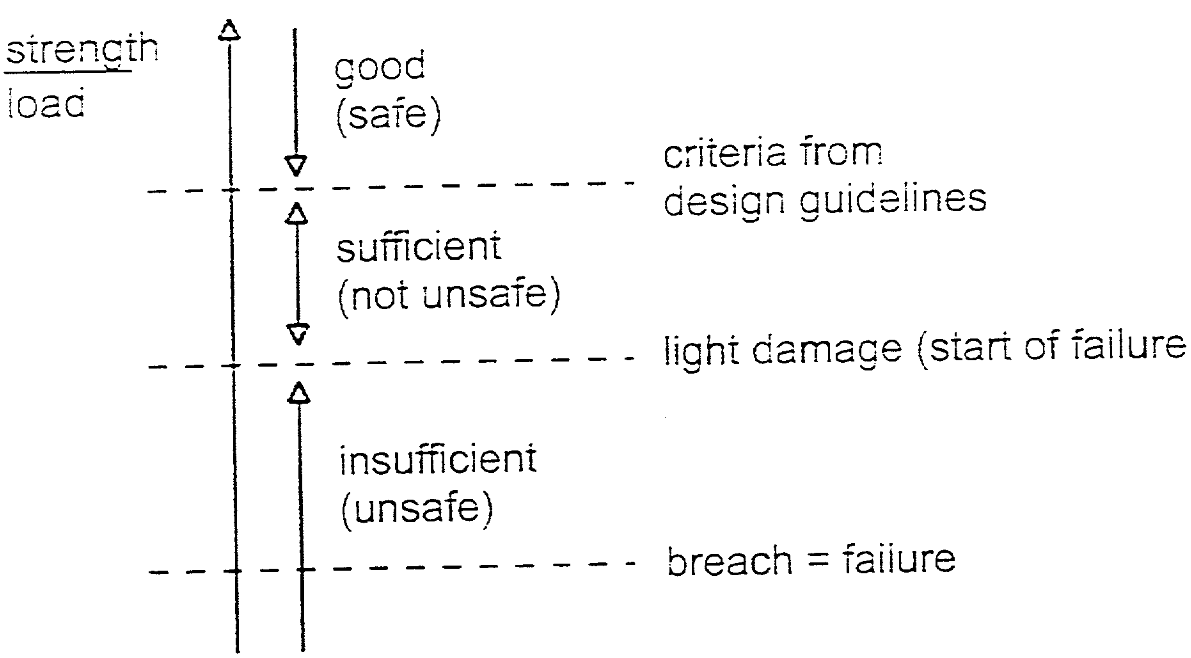
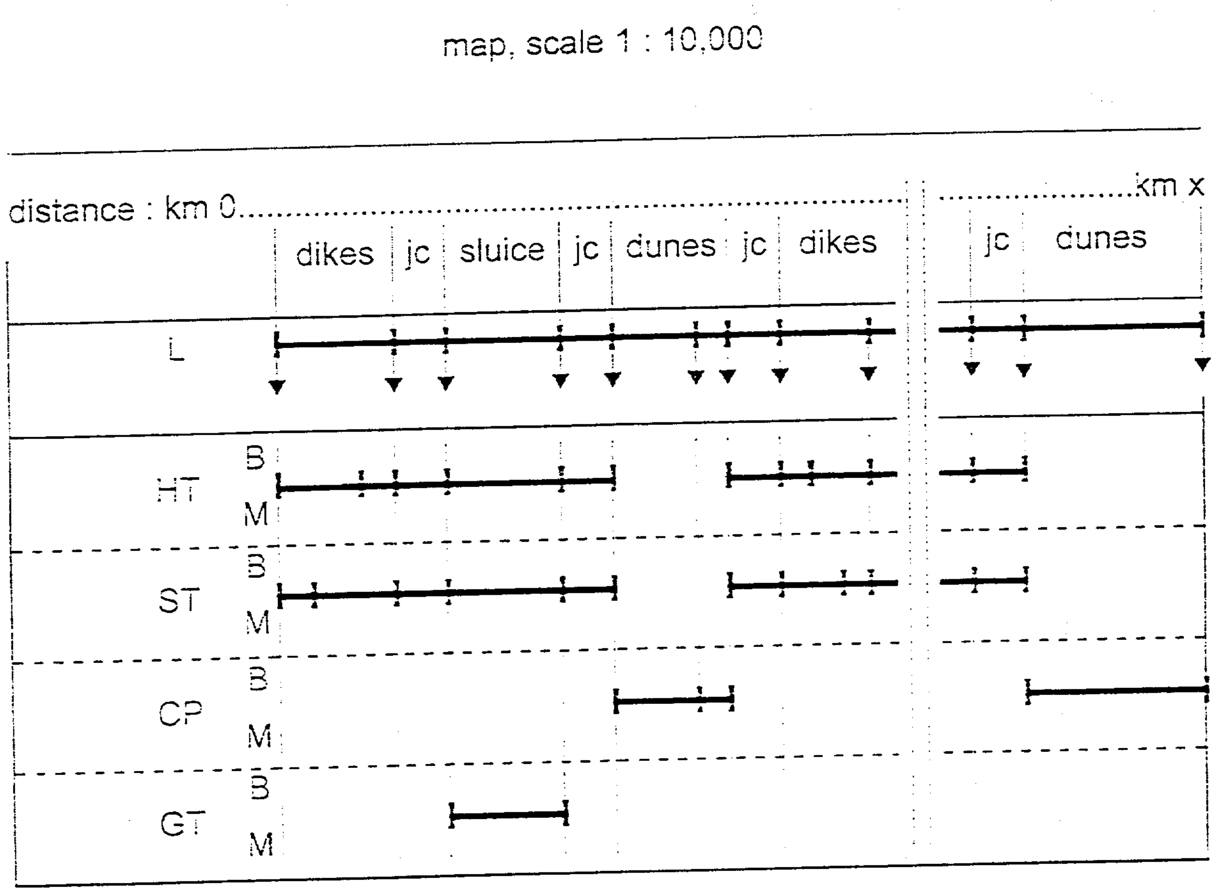


Figure 3 Fail route and assessment scores

structure type	assessment track
dikes, dams	HT, ST ST: STU, STV, STM, STP, RV STV: LQ, SF RV: RVS, RVT, RVR
sluices, storm surge barriers	HT, ST, GT ST: STP, STC GT: GTS, GTC
dunes	CP
pipes/cables houses trees	
junctions	one ore more of the above-mentioned

HT = height
ST = stability
STU = micro stability inner slope
STV = macro stability outer slope
STM = macro stability inner slope
STP = piping
STC = structure stability
LQ = liquefaction
SF = sliding of foreshore
RV = revetment
RVS = sliding of revetment
RVT = stability of toplayer of revetment
RVR = residual strength of revetment
GT = gates
GTS = gate structure
GTC = gate control
CP = critical profile

Figure 4 Assessment tracks



g = good
s = sufficient
i = insufficient
d = doubtful, no score, to be investigated
jc = junction
L = load
B = score, based on experience of the dike manager
M = score, based on calculation results

→ Example:

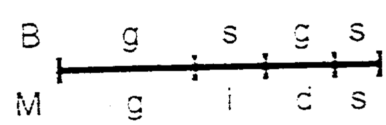


Figure 5 Assessment form

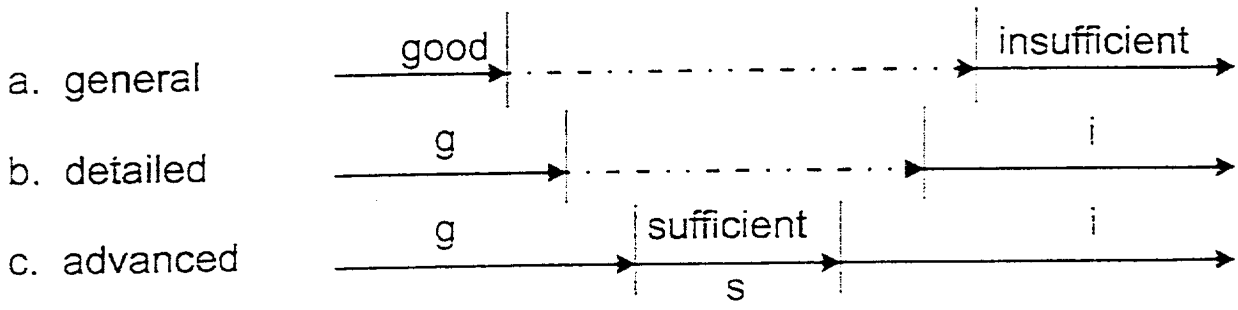


Figure 6 Assessment levels

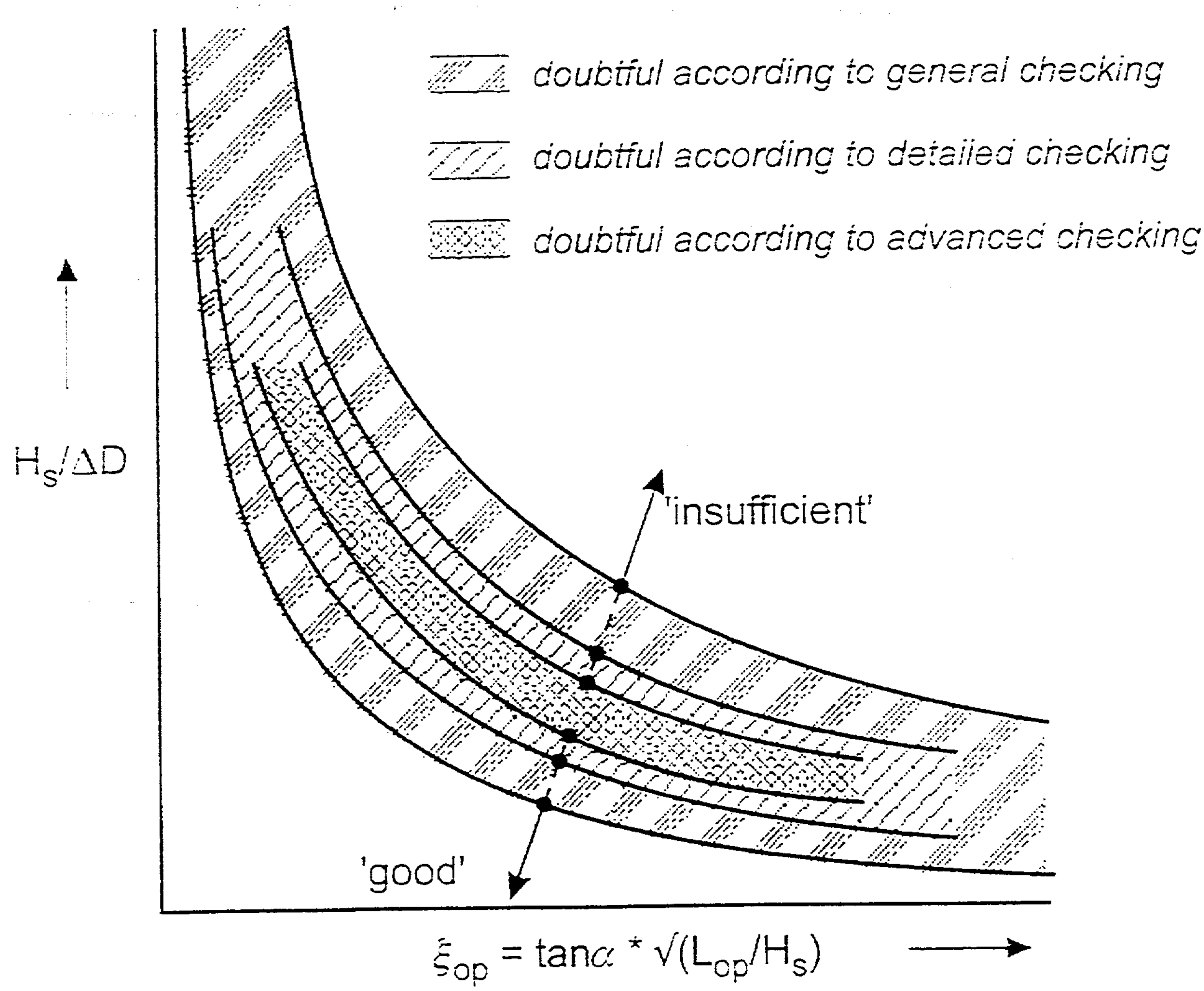


Figure 7 Pitched slope protection: schematic representation of the 'gray' zone in which the stability is doubtful

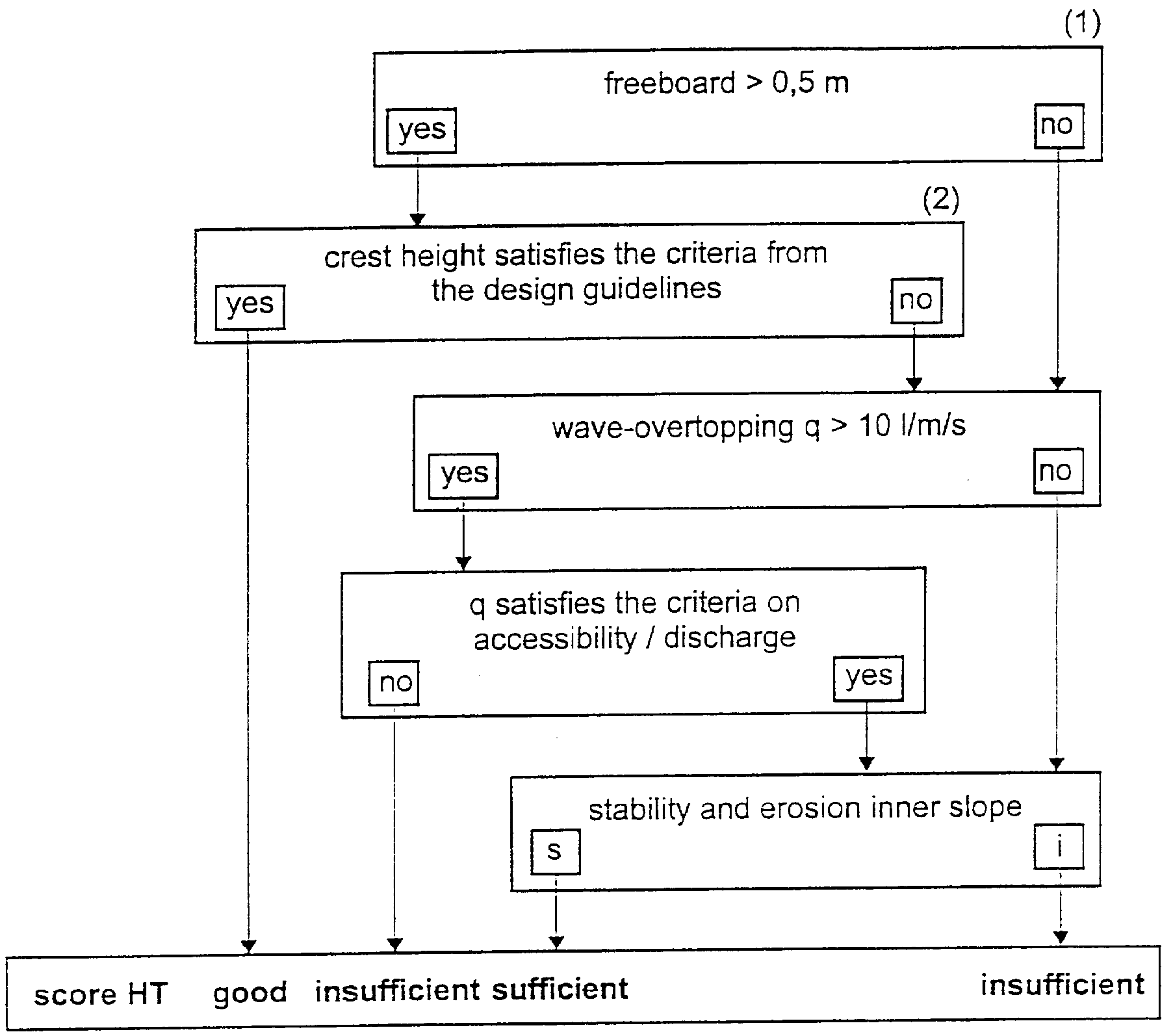


Figure 8 Assessment track of the crest height of a river dike (HT)